THE AMERICAN MINERALOGIST
JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA
VOL. 9 JUNE, 1924 No. 6

NOTE ON ANDALUSITE FROM CALIFORNIA: A NEW USE AND SOME THERMAL PROPERTIES

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The andalusite here described is found at an elevation of 10,000 feet on the southwestern slope of White Mountain, in the White Mountains of the Inyo Range, Mono County, California. The deposit itself is located across a canyon about two miles east and north of an occurrence described by Knopf.[1] The andalusite reported by Knopf, however, is at present of no commercial value owing to the fact that it carries an excessive amount of quartz.

MINERALOGY

OCCURRENCE AND PHYSICAL PROPERTIES. The main mass of the andalusite rock can probably best be described as coarse granular, and is generally of a gray or light pinkish-brown color. On exposed surfaces the color is yellow-brown due to oxidation.

The texture of the rock varies greatly. Many large fragments show a very distinctly coarse radial or columnar structure, definite rough crystals four or five inches in length being noted. At the other extreme are smaller areas which have a very fine granular texture, sugary appearance and are very friable, breaking down readily into a fine sand. While the material is generally quite compact, there are occasional large cavities and in these are sometimes found excellent groups of large coarse crystals at times reaching five inches or more in length.

The color of the material shows variation also. Crystals are generally white on the exterior portion but when broken show directly beneath the surface a pale apple-green color. Columnar or radial masses also show green or gray color but granular masses are usually white, gray, or pinkish-brown. This latter color is in reality due to inclusions of scattered rutile grains or crystals, as can readily be observed when examined microscopically.

CRYSTALLOGRAPHY. The crystals appearing in cavities are generally rather simple in form but of uncommon habit for andalusite. This probably accounts for the fact that of all those to whom a group has been shown, no one has as yet named the crystals as andalusite. The crystals are usually covered with a thin white coating which is dull and somewhat rough, so that accurate measurements of the crystal angles are impossible. Contact goniometer measurements, however, show sufficiently close agreement to the theoretical values to establish the forms present. The crystals usually occur in more or less parallel groups terminated at one end only and are also attached to each other by the prism faces so that the prism zone is generally only partially complete.

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[1] *Journ. Wash. Acad. Sc.*, 7, 549 (1917).

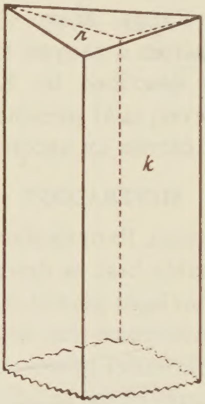

FIG. 1

Figure 1 shows the development of a typical crystal. The predominant prism is *k* (210) and the end of the form is terminated by the dome *r* (101). Measurements of the angles are as follows:

	OBSERVED	CALCULATED
kk'''	62–51°	52° 30′
rr'	72	70 56

The prism faces on the larger crystals are somewhat rounded, hence the variation in the angles noted for this form. Faces of the smaller crystals, however, give values close to those calculated for the form. Owing to the fact that the ratio of *a* : *b* in andalusite is nearly 1:1, the angles for the forms (210) and (120) are very similar. It was necessary, therefore, in this case to make a thin section parallel to the base and determine the position of the optic plane. This was found to be in the short diagonal and being parallel to the *a*-axis, the prism then is established as *k* (210). It follows that the dome is *r* (101) and not *s* (011); these two forms also possess very similar angles.

CHEMICAL COMPOSITION. On the whole the rock material is a rather pure andalusite with comparatively small amounts of several other minerals. During mining, the material is constantly checked by specific gravity determinations on a Jolly balance. Samples are taken over the face of the working and if favorable, the material is broken out, carefully hand selected and sacked. Generally the material runs at least 75-85% andalusite upon microscopic examination. A typical chemical analysis from a sample representing a carload shipment, recalculated to an Al_2SiO_5 basis, will show over 90% Al_2SiO_5. Such an analysis follows:

ANALYSIS		EQUIVALENT TO	
SiO_2	33.78	Al_2SiO_5	94.18
Al_2O_3	56.89	SiO_2	0.22
H_2O	0.37	Others	5.60
Ign. loss	3.67		
Other deter. constituents	5.37		
	100.08		

The fact that the chemical analysis generally shows higher Al_2SiO_5 than is indicated by the microscopic examination is due to the frequent occurrence of corundum in the material. In no case do the associated minerals assume any large proportion over any considerable area, although locally they may occasionally outweigh the andalusite.

ASSOCIATES. The associates of the andalusite are also deserving of mention, especially since several are considered among the less common minerals.

Lazulite is perhaps the most unusual mineral associated with the andalusite. It occurs in small blue-green veinlets or masses scattered through the mass. Optically it shows a distinct light blue pleochroism. Chemical analysis usually shows small amounts of P_2O_5 present in the rock.

Pyrophyllite is another uncommon mineral found with the andalusite. It occurs in crusts of radial fibers on the walls of cracks or as radial masses in small cavities. Owing to its chemical composition, as soon as its water is lost it takes on nearly the same composition as andalusite and hence can hardly be considered as an impurity.

Muscovite also occurs in much the same manner as pyrophyllite and is somewhat more abundant but at no time reaches large proportions. It occurs in distinct plates, usually in divergent groups.

Corundum is a rather common associate of the granular andalusite and is usually deep sapphire-blue in color. It is generally in small scattered plates or grains but occasionally may form lenses two or three inches in size. According to observation thus far it is always blue in color. In a few instances crystals of andalusite with blue corundum centers have been noted. For manufacturing purposes a small amount of corundum is favorable to the neutralization of the effect of any excess quartz in the rock.

Rutile is a rather constant associate, largely as microscopic inclusions in the andalusite. At times small free crystals can be found. The constant association of rutile and the blue color of the corundum would seem to confirm the theory that the color of sapphire is due to the presence of TiO_2.

Pyrite is sometimes found locally, especially near open veins. When near the surface it has often weathered leaving a stained and porous rock.

The absence of quartz is very noticeable. It is almost never found in the andalusite proper but is confined to veins crossing the mass.

Barite also has been noted a number of times; one large right angled twin having been found.

Lazurite also has been found, not in the andalusite but in veins of milky quartz adjacent to the mass. It is of interest to note that Knopf points out that the occurrence examined by him across the canyon and to the southwest, was first staked as a silver mine, the bright blue lazurite being mistaken for AgBr. After an assay showed silver to be absent the claim was dropped. Later the brown andalusite mass was staked again, this time under the impression that it was apatite. This in turn proved valueless and was relinquished.

USE

This deposit of andalusite serves as an extremely good example of a comparatively useless, rare, or "museum" mineral becoming common enough to be available on a commercial scale. Heretofore it has been observed only in small scattered masses or crystals. At the same time it has found a commercial use, until at present about 70 tons per week are being mined. Both of these developments have been the result of patience and thorough scientific research.

For some years the manufacture of the porcelain core of the most modern type of automobile spark plug has tended toward the formation during the burning process of an increasingly higher content of a crystalline compound, thought to be an "artificial sillimanite." Bowen[2] has recently shown, however, that in artificial melts consisting of Al_2O_3 and SiO_2 in varying proportions the compound $Al_2O_3.SiO_2$ corresponding to natural sillimanite does not form as has been stated in an earlier work on the subject, but that the compound formed has a composition $3Al_2O_3.2SiO_2$. Not only is this compound similar chemically to sillimanite but its physical and optical properties are remarkably similar as well.[3]

This "artificial sillimanite" produced in ceramic ware results from the molecular changes taking place in clay under the influence of heat and various fluxes. The highest content of "sillimanite" has been developed by introducing into the unburned body artificially prepared "sillimanite" in the form of a calcine, a mixture of clay, alumina, and fluxes, heated to a high temperature of about 1500°C. This was of course an expensive method to obtain the desired end although it has been used for several years in the manufacture of spark plugs.

In order to eliminate the necessity of making an "artificial sillimanite," the logical procedure was to turn to one of the natural Al_2SiO_5 compounds, namely, sillimanite, andalusite, or cyanite, but here the difficulty of obtaining any of these in sufficiently large quantities and in a pure state presented itself, until the California andalusite deposit was discovered.

Careful research was then able to substitute this natural material for the "artificial sillimanite" with the result that not only was the manufacture less expensive but also the resulting article was better than the previous one.

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[2] N. L. Bowen and J. W. Greig, *J. Am. Cer. Soc.*, 7, 238-54 (1924).

[3] In the original manuscript of the present paper the writer regarded the crystalline compound formed by the inversion of andalusite and cyanite and the crystals formed in porcelain as sillimanite, following the earlier work of the Geophysical Laboratory on the system $Al_2O_3 \cdot SiO_2$. Since the announcement of the work of Bowen and Greig it has been necessary in several cases to change "sillimanite" to the new compound "$3Al_2O_3 \cdot 2SiO_2$." This statement is made so that full credit may be given to them for the facts they have discovered and the writer's sincere thanks are due Dr. Bowen for his kindness in allowing this use of his manuscript before its actual publication.

THERMAL CHANGES

Although the material is introduced into the clay body of the unburned porcelain core as andalusite, certain changes take place during the burning process and as a result of these no andalusite is present in the finished product but all of it undergoes a molecular change to a compound of the composition $3Al_2O_3 \cdot 2SiO_2$ with excess of a glass highly siliceous in composition.

This change is quite definite, taking place sharply and at a definite temperature. Under manufacturing conditions this temperature is in the neighborhood of cone 13 on the Seger scale (theoretically equal to 1390°C but actually probably considerably lower).[4]

Of interest from the microscopic standpoint is the behavior of andalusite during this change. Up to the inversion point andalusite retains all of its original optical properties except for the formation of small glass-like inclusions which apparently represent the fusion of included impurities. At the inversion point the clear homogeneous grains of andalusite give way to grains composed of fibrous or columnar crystals, each crystal parallel to the adjacent one with a narrow strip of glass between. The result is instead of a clear grain, a grain composed of a group of parallel crystals having all of the optical properties of $3Al_2O_3 \cdot 2SiO_2$, with glass between each. Traces of the remains of such structures can sometimes be seen in a section of a finished spark plug core.

Cyanite also changes to $3Al_2O_3 \cdot 2SiO_2$ and glass under heat but at a temperature of about cone 11 (theoretically 1350°C). The structure developed is also different from that shown by the change in andalusite. Cyanite yields a "sillimanite body" consisting of groups of interlocking fibers of $3Al_2O_3 \cdot 2SiO_2$ which are not parallel over any considerable length. Along with these are areas of glassy matter, generally more abundant than in the andalusite and due no doubt to the fact that cyanite is less pure as a rule than andalusite.

The fact that andalusite changes to $3Al_2O_3 \cdot 2SiO_2$ at a temperature considerably below the final temperature to which the porcelain is burned has a very practical value because in this change from andalusite to $3Al_2O_3 \cdot 2SiO_2$ and excess siliceous glass there is an increase in specific gravity and a consequent decrease in volume. This volume change tends to produce strains in the porcelain, which can be absorbed if the inversion takes place well below the final burning temperature. If this were not true and the change took place near the final temperature, a decidedly weaker porcelain might result.

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[4] The statements made here are purely provisional. The writer expects to investigate the changes with temperature in more detail at a later date.

Incidentally, during this inversion the andalusite does not outwardly break down and lose its original form, so that good artificial pseudomorphs of this mixture of $3Al_2O_3 \cdot 2SiO_2$ and glass after andalusite are readily obtained by simply heating for a sufficiently long period above the inversion temperature. This can not be done with cyanite because the expansion at the inversion point is so great that the cyanite breaks down into a chalky, friable mass.

The writer here wishes to acknowledge his sincere thanks to Dr. J. A. Jeffery, President, and Mr. F. H. Riddle, Research Director of the Champion Procelain Company, whose interest and co-operation have made this note possible.

AN UNUSUAL OCCURRENCE OF CYANITE

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In the Reed-Wekusko Map-Area in Northern Manitoba a series of sediments has been mapped by Dr. F. J. Alcock of the Geological Survey of Canada as the Wekusko series, which he describes as follows:

> The Wekusko series consists of gneisses and mica schists most of which are believed to be of sedimentary origin. The paragneisses are finely banded rocks locally showing distinct bedding and crossbedding and with conglomeratic horizons. They vary from light gray to dark gray in colour. They consist of quartz, feldspar, biotite and usually garnet. The mica schists vary considerably depending on the kind of secondary silicates developed in them: garnet, staurolite, and garnet-staurolite types are the common varieties and in one locality a cyanite-bearing schist is associated with the other types. Five distinct areas of these rocks occur in the Reed-Wekusko sheet. . . . Immediately east of the outlet of Anderson lake a ridge approximately 1500 feet long and from 100 to 200 feet wide extends in a northeast direction. The ridge is bordered on the west by low, swampy land facing Anderson lake and on the east by a stretch of muskeg 150 feet wide, to the east of which runs a ridge of red granite-gneiss. The ridge of schist is well exposed throughout: it has been heavily glaciated and shows big grooves and furrows, one of which is 8 feet in width and 6 feet in depth. Like the paragneiss many varieties are met with and all gradations from the garnet gneiss to micaceous schists containing abundant staurolite crystals are encountered. The commonest variety is a biotite schist containing both staurolite and garnet. Towards the northeast end of the ridge a garnetiferous mica schist is developed in which garnet rhombic dodecahedrons, varying in size up to 2½ inches in diameter in places, comprise most of the rock.

> The series consists of staurolite, cyanite and garnet schists striking north 35 degrees east and dipping at an angle of 70 degrees to the northwest away from the adjacent granite-gneiss. The dominant rock variety is a green chlorite schist containing crystals of cyanite, staurolite, and garnet. Certain bands show large fans of white and reddish cyanite standing out prominently on the weathered glaciated surface. Bands in which staurolite crystals are predominant are also common, the staurolite crystals reaching in places a length of 2½ inches. Two bands averaging 3 feet in width are of a light coloured schist made up of quartz, muscovite, biotite, and small crystals of staurolite.
>
> The staurolite and cyanite crystals for the most part lie in rows which seem to represent original bedding planes. The bands are commonly wavy suggesting drag folding on a small scale in the beds, a feature which is emphasized in places by narrow crenulated bands of quartz."[1]

The staurolite-garnet-cyanite phase of this sedimentary series is of special interest, both on account of the unusual colour of the cyanite, and of the exceptional occurrence of the mineral in a series where elsewhere in the same series staurolite and garnet occur not infrequently in close relationship. The series, which is interbedded with basic and acid lava flows of early Pre-cambrian age, has suffered intense dynamic metamorphism during the movement which accompanied the intrusion of the granites, which are now exposed in various parts of the field. As a result of this movement have been formed the minerals which characterize the series—quartz, biotite, muscovite, chlorite, staurolite and garnet. The latter two minerals are found in bands in the schist far removed from contact with the granite, and are apparently genetically connected with the chemical composition of the sediments as well as with the degree of metamorphism to which the sediments were subjected. On the north shore of Snow lake, for example, immediately northwest of the old Anderson cabin, a well defined staurolite schist is exposed some 5 miles distant from the nearest granite outcrop. The staurolite bands clearly represent old bedding planes, striking 323 degrees, and dipping 40 degrees northeastwards while the strike of the schist is 23 degrees, and the dip 70 degrees eastwards. The staurolite bands alternate with a fine grained, pepper and salt mica schist, in which considerable garnet has been developed. Small bands of quartz run with the bedding planes, and have been crenulated by the shearing. The shearing has also affected the orientation of the staurolite crystals, which are arranged with their vertical axes in the main in the shearing planes, though the banding is parallel to the planes of sedimentation. Typical of the occurrence of staurolite is the tailing off of the crystals into lenses of quartz, which owing to intergrowth with fine plates of muscovite in parallel arrangement, resemble somewhat groups of fibrolite crystals. The constant association of quartz with staurolite would suggest that a certain transference of quartz from the siliceous bands took place during the shearing process, and that the staurolite crystallized in a siliceous bath. There is evidence also that staurolite crystallized late in the period of mineral rearrangement, as the flakes of muscovite and biotite are frequently bent round the crystals of staurolite as though by force of crystal growth of the staurolite. Quite commonly also the garnets, which are in this locality small, are arranged on the margin of the staurolite crystals, in a position which indicates that they were formed before the growth of the staurolite crystals had been completed.

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[1] The Reed-Wekusko Map-Area. F. J. Alcock. **Mem. 119.** *Geol. Surv. Can.*, 21-22, (1920).

The Snow lake occurrence may be taken as representative of the staurolite-garnet development in the Wekusko series, though somewhat exceptional in the clearness with which the bedding planes are defined. No clue was found in the field as to special temperature or pressure conditions which might give rise to the development of staurolite and garnet where elsewhere in the series mica schist, mica-hornblende schist and chlorite schist, with invariant quartz and occasional feldspar, occur as the dominant rock types. In a region of widespread plutonic action it is not possible to assume that contact metamorphism from the roof of a batholith, near the surface but not exposed, may not have played the principal part in the formation of staurolite and garnet: but the elongation of the mineral bands along bedding planes points to the chemical composition of certain beds as the controlling factor in the mineral expression.

A very interesting case of metamorphism is that referred to by Alcock (*vide supra*) from the east end of Anderson lake, west of a granite contact. This is the only known occurrence of cyanite in the Wekusko series, and apparently the only recorded occurrence of a reddish cyanite. The locality is interesting as well on account of the exceptional development of garnets which rival in size and beauty the best garnet occurrences of this continent. The following is the rock gradation southeastwards (towards the granite) across the strike, which varies from 20 degrees to 50 degrees east of north:

(1) Compact mica schist, light coloured, with abundant quartz.
(2) Cyanite schist, the cyanite appearing in reddish rosette-like aggregates and in white tufts on the weathered surface.
(3) Staurolite schist, with numerous tufts of white cyanite.
(4) Chlorite schist with large garnets—a wide zone.
(5) (Across a muskeg) Pepper and salt biotite schist grading eastward into contact rock, in which considerable epidote has been developed. Beyond this lies the granite.

The cyanite appears in clusters and tufts, seldom in isolated crystals. It invariably shows a reddish tint, except where the mineral has weathered white. No blue crystals were found. The cyanite band No. (2) in the above description, to the naked eye seemingly free from staurolite, is the narrowest band in the series, with a maximum width of 6 feet. In band No. (3), in which staurolite accompanies the cyanite, the crystals of staurolite are not so well developed as in the Snow lake occurrence, while the tufted cyanite runs in lines across the strike of the schist, as though in lines either of original bedding or of secondary shear.

The microscopic examination reveals the following facts:

(a) While the staurolite appears on field examination to be restricted to band No. 3, it is in reality present in all the bands from No. 1 to No. 5 It persists from the immediate vicinity of the granite into the normal dynamically metamorphosed sediments

(b) Both garnet and cyanite are restricted in range, garnet near the contact, and cyanite further removed. Staurolite accompanies both minerals.

(c) Biotite has suffered more complete change to chlorite in the near vicinity of the granite than at a greater distance, very complete, for instance, in bands No. 4 and No. 5, not at all in No. 1.

(d) The variety of minerals is very limited: quartz, biotite, chlorite, staurolite, cyanite, garnet, a little muscovite. Feldspar is very rare.

(e) Quartz has crystallized in part before garnet, staurolite and cyanite, and occurs very abundantly as inclusions in these minerals. The crystallization of quartz was not completed until after these minerals had ceased to grow. Staurolite crystallized somewhat earlier than garnet, whose period of crystallization began before the completion of growth of the staurolite crystals, and ended before biotite ceased to crystallize. The relationship of staurolite to cyanite in this connection was not determined.

(f) The structure is that defined by Grubenmann as crystalloblastic. There is a definite parallelism in the arrangement of the minerals, but no indication of strain. Owing to concurrent crystallization with quartz, the staurolite, cyanite and garnet show no well defined crystal outlines: they appear rather as skeletons and filaments intergrown with granular quartz. The outlines of the quartz crystals, on the other hand, are well defined. Where staurolite or cyanite reach large size, the structure is more definitely porphyroblastic.

(g) The cyanite crystals are in thin section colorless, or show slightly reddish tint, with very faint pleochroism. The cleavage (100) is pronounced, usually in the direction of crystal elongation and in the plane of schistosity of the rock. There is an interesting exception in band No. 3, where the cleavage lines swing from the plane of schistosity to an angle of 43 degrees with that plane. (See Fig. 1.) This is a rather remarkable illustration of the effect of movement through pressure, during the period of crystallization, in overcoming the natural tendency of the crystal to grow in the direction of its *c* axis. A close study of the microphotograph will reveal the fact that there is even in this case, in places, an elongation along the cleavage lines, but broken by the very definite bands of quartz crystals in the direction of movement. On the (010) face, the angle of extinction varies from 3 to 7 degrees, measured from the (100) cleavage trace. In sections on the (100) face, the extinction angle is 30 degrees with the fair cleavage trace of (010). An irregular basal cleavage is also noted.

Fig. 1. Cyanite with cleavage lines oblique to schistosity. (Plane polarized light)

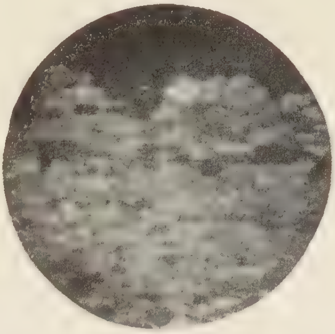

Fig. 2. As in Fig. 1. (Between crossed nicols)

Staurolite shows the characteristic pleochroism from straw yellow to brownish red, is even more completely pitted with quartz inclusions than is the cyanite, and is intergrown with quartz and shreds of muscovite. In cross section imperfect traces of the (010) cleavage are noted. As in the case of cyanite, the elongation in the plane of schistosity is not invariably along the *c* axis of the crystal. In both cases, apparently, the initial growth of the crystals took place irrespective of stress planes, and the position of crystal axes remained unchanged as growth proceeded. One might suggest that staurolite and cyanite, two aluminous silicates, grew originally along planes of sedimentation, and that later or more pronounced stress movements influenced the direction of extension of crystal growth, but left the orientation unaffected.

The garnet is pink in transmitted light, full of well formed quartz crystals, and definitely later than the earliest stage of staurolite crystallization, and earlier than biotite, between which and the garnet some resorption has taken place. In thin section the garnet appears as skeletal crystals, with little suggestion of the very perfect dodecahedral outlines which are characteristic of the large crystals of the garnet zone.

GENETIC RELATIONSHIPS. In a contact zone garnet, staurolite and cyanite have developed in a quartz-mica schist, which forms part of a sedimentary series where elsewhere garnet and staurolite, unaccompanied by cyanite, occur in bands far removed from surface contacts. The absence of sericite and of feldspars points to a low content in alkalies; the abundance of quartz and the aluminous silicates, to a high silica-alumina content. The typical gneiss of the sedimentary series has the following analysis,[2]

SiO_2	63.84%
Al_2O_3	20.34
Fe_2O_3	3.34
FeO	3.98
MgO	2.20
CaO	0.64
Na_2O	0.95
K_2O	2.42
H_2O	1.05
TiO_2	0.80
	99.56

The conditions favorable for the formation of cyanite would appear to be (a) excess of alumina and low content in alkalies and alkaline earths, and (b) high temperature conditions, though not so high as would necessitate the crystallization of the silicate of alumina as sillimanite. In general, staurolite is a high pressure mineral,[3] with pressure as a factor of greater significance than temperature, while garnet may form under a greater range of pressure and temperature conditions than either of the other two minerals. In contrast to garnet and staurolite, the stability of cyanite would appear to be here conditioned by proximity to igneous intrusion; for it is improbable that no sediments occur elsewhere in the series with similar high-alumina, high-silica, low-alkali content to that single band in which cyanite has been developed. The complete absence of sillimanite in a band of this composition would seem to be conclusive evidence that the temperature of formation of the metamorphic minerals was less than that which conditions the 'deep zone' of Grubenmann. The mineralization of the whole sedimentary series suggests rather a gradation from 'upper zone' temperatures, where not directly affected by igneous intrusion, to the 'middle zone' conditions where the intrusion of igneous batholiths raised the temperature of crystallization in the vicinity of the igneous bodies.

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[2] F. J. Alcock, *loc. cit.*, p. 22.

THE ORIGIN OF A NITER DEPOSIT NEAR DUBOIS, IDAHO[1]

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In the fall of 1922, while the writer was mapping the geology of the lava plain near Dubois, Idaho, his attention was called by Mr. Murray McWhorter to a deposit of a white crystalline salt in a cave in sec. 22, T. 11 N., R. 36 E. This salt was found to be practically pure potassium nitrate.

The niter sputters when ignited on charcoal, and under the microscope it is optically biaxial with a very small angle. The crystals vary in size, the maximum being about 1 millimeter in diameter. Analysis of a sample of the niter by Earl V. Shannon[2] gave the following results:

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[3] F. Becke, *Fortschr. d. Min. Kryst. u. Petr.*, 5, 223, (1916).

[1] Published by permission of The Director, United States Geological Survey.

[2] Shannon, E. V., Nat. Museum, Washington, D. C.

ANALYSIS OF NITER DEPOSIT

CaO	None
KNO_3	98.74
$NaNO_3$	1.74
Cl, CO_2, SO_3	Traces
$Al_2O_3+Fe_2O_3$	Traces
H_2O below point of fusion	.12
Insoluble in water	.24

The cave in which the niter was found is located in a recent basalt flow and was caused by the doming of the crust of the flow by pressure while the lava was still viscous below. A small opening about 1½ feet in diameter on the west side of the pressure dome indicates the presence of the cave. The cave is about the size of a small room and is partially filled with wind-blown silt. The roof is composed of typical blue basalt from 1 to 5 feet thick, and is covered with small lava stalactites. It is these stalactites that indicate that the cave was formed by a doming of the crust while the interior of the flow was still liquid. The exterior surface of the roof is dusted over with one-half to 2 inches of wind-blown soil, and is broken by numerous joint cracks caused by the shrinking of the basalt as it cooled. Most of the cracks extend downward and are visible on the under side of the roof, especially where the stalactitic coating has scaled off. It was in these joint cracks, ⅛ to ¼ inch wide, and adhering to the roof adjacent to the cracks that the white crystals of niter were found. The niter was quite compact, and it was necessary to use a knife to scrape it off.

Mr. McWhorter reported that he had removed all the niter from the roof of the cave the previous year. As the writer had no trouble in collecting several ounces of it, the niter is evidently being deposited at the present time.

This fact led to a close examination of the conditions above the cave in order to determine its origin. The ground surface above the cave was covered with the excreta of sage hens, birds occurring in large numbers in the lava fields of southern Idaho. From this excreta bacterial action would develop nitrates. Percolating waters would carry the nitrates downward through the joint cracks and concentrate them on the roof of the cave by evaporation.

The accumulation of excreta on that particular spot is due to special conditions. The morning the writer visited the cave he noted that a flock of sage hens took flight from the area immediately over the cave where they had evidently been roosting overnight. The ground directly over the cave was bare although there was about 2 inches of snow on the ground elsewhere. The temperature inside the cave at the time was about 50°F., while the temperature outside was below freezing. Thus there was evidently sufficient heat radiating upward through the roof of the cave to keep the ground free of snow. This condition is known to prevail until late in winter. This snow-free spot being warmer than the neighboring area becomes a favorite roosting place for the sage hens during cold fall nights, and accounts for the amount of excreta found there. In short, the warmth of the ground above the cave makes this spot a favorite habitat for sage hens; excreta accumulates; bacterial action develops nitrates from it; percolating water carries the nitrates downward through joint cracks; and finally, evaporation concentrates them in the cracks and on the roof in the form of crystalline niter.

The thinness of the roof precludes the possibility of the potassium nitrate being leached from the basalt itself. Further, the fact that the niter is being deposited at the present time eliminates the chance of it having been formed from volcanic exhalations before the lava cooled.

In 1900, Hess[3] advanced the theory that niter deposits in caves were caused by percolating waters leaching the soluble salts from the soil above the cave and subsequently depositing it inside of the cave due to the evaporation of the water. With reference to this article, Nichols[4] stated that he believed the majority of niter deposits were formed from nearby guano deposits, but that Mr. Hess had pointed out a new method by which cavern deposits might be formed. Later, from numerous field observations, Gale[5] concluded that the majority of the cavern deposits of nitrates were derived from the decomposition of guano.

Because of the thinness of the soil overlying the cave near Dubois and because the topographic position of the cave makes it impossible for the water to come from nearby areas, it is evident that the deposit in this cave could not have been derived from soluble salts in the soil. The conditions of occurrence of this niter deposit seem to the writer conclusive evidence that at least this niter deposit was formed by the leaching of guano.

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[3] Hess, W. H., "The Origin of Nitrates in Cavern Earths." *Jour. of Geol.*, 8, 129-134, (1900).

[4] Nichols, W. H., "Nitrates in Cave Earths." *Jour. of Geol.*, 9, 236-243, (1901).

[5] Gale, H. S., "Nitrate Deposits," *U. S. Geol. Survey, Bull.* 523, 35, (1912).

BOOK REVIEW

FIELD BOOK OF COMMON ROCKS AND MINERALS. Frederic Brewster Loomis. 278 pages with 32 colored plates and 100 illustrations. G. P. Putnam's Sons, *New York*, 1923.

The purpose of this field book as stated by the author "is first of all to provide a means of identifying minerals and rocks by such methods as are practical without elaborate equipment or previous training: and second to suggest the conditions under which the various minerals and rocks were formed. . . ."

Naturally, in a book of this type, designed "to make the study of minerals and rocks so direct and simple that everyone can get a start," the treatment and presentation must be quite different from that of a text book on the subject and judgment should be tempered accordingly. The author has attempted to arouse an interest in minerals by a very liberal use of colored plates and illustrations: in fact, 32 colored plates and over 100 other illustrations from photographs are distributed throughout the 278 pages. Many of the plates are of exceptional character and vividly portray the true color of the mineral represented. Some of the line drawings, however, are not so well executed and quite a few are not properly oriented.

About two-thirds of the book is devoted to descriptive mineralogy and the scheme pursued is that of grouping together all minerals with a common element. Like many first editions the book contains its full quota of typographical errors. There are in addition, however, certain errors which could hardly be classified under this heading. A few illustrations will be noted: the ruby owes its color to iron oxide while cobalt is responsible for the blue of sapphire (p. 24); the formula of limonite is given as $2\ Fe_2O_3{\cdot}3H_2O$ (p. 49); the color of rose quartz is said to be due to titanium (p. 104); the formula of opal is given as $SiO_2{\cdot}H_2O$ with about 10% of "water of crystallization" (p. 108); calcium sulphate, we read is precipitated from sea water when 37% of the sea water is evaporated (p. 150); while among the uses of gypsum the following sentence is encountered, "the gypsum is first heated to about 400° C, which drives off the water of crystallization and causes it to crumble to a powder which is plaster of Paris."

Seventy-seven pages are devoted to a discussion of rocks. The material presented in this section is well chosen and quite adequate for the purposes intended. Miscellaneous subjects as concretions, geodes, meteorites and fossils are briefly described in 20 pages.

A bibliography is appended but not one that is up-to-date, as evidenced by the following reference to The American Mineralogist, "a monthly magazine for minerals, H. W. Trumbell, Philadelphia."

The book in spite of its minor imperfections should, largely by virtue of its numerous illustrations, be of considerable assistance to a beginner.

W. F. H.

NOTES AND NEWS

Dr. George Otis Smith, director of the Geological Survey, Rear Admiral Hilary P. Jones, president of the General Board and Commander-in-chief of the United States Fleet, and Professor R. D. Bush of the Bureau of Mineralogy of the State of California, have been appointed by President Coolidge as a special commission to study the problem of conserving fuel oil for the navy and providing facilities for storing fuel.

Recent experiments conducted at the U. S. Bureau of Standards show that by saturating a sandstone for several hours in melted sulphur and then cooling it the strength of the stone is increased from 200 to 300 per cent. The crushing strength of the ordinary sandstone is about 8000 pounds per square inch, but after the sulphur immersion the crushing strength reaches approximately 30,000 pounds, or equal to that of the best granite. Investigations are still in progress to determine the weathering qualities of the treated sandstone.

Dr. Grubenmann, professor of geology and mineralogy at the University of Zurich and at the Federal Polytechnic Institute, has died at the age of seventy-four years.

Dr. William Nicol, professor of mineralogy at Queen's University, Kingston, Ontario, from 1893 to 1915, died at his home in Kingston, February 24th.

A new method for the production of phosphoric acid has been perfected by the Bureau of Soils of the U. S. Department of Agriculture. It consists in smelting phosphate rock after it has been briquetted with silica and carbon. The phosphorus is volatilized as phosphoric anhydride and then condensed. This concentrated product can be shipped in lead-lined or wooden containers and upon reaching its destination can be diluted and reduced in strength to that required for utilization by crops.

Dr. W. Ch. Brögger, professor of mineralogy in the University of Christiania, has been elected corresponding member of the Prussian Academy of Sciences in the physical-mathematical section.

Due to some error in the mailing of the March issue, a number of subscribers have been overlooked. If those who have not received the March number will kindly make this fact known to the editor copies of this issue will be forwarded at once.

Mineral collectors and dealers will be interested in a pamphlet recently published by Frederick A. Canfield of Dover, New Jersey, entitled "The Final Disposition of some American Collections of Minerals." The pamphlet contains in concise form statements concerning 172 collections.

Dr. R. C. Wallace, professor of geology in the University of Manitoba, has been elected president of the Canadian Institute of Mining and Metallurgy.

ABSTRACTS

A NEW OCCURRENCE OF VANADINITE IN THE MARICO DISTRICT, TRANSVAAL. P. A. Wagner. *Trans. Geol. Soc. S. Africa*, **23**, 59-63, (1921); thru *Chem. Abstr.*, **16**, 2653.

Vanadinite is associated with galena and cerussite in an ore deposit near Ottoshoop. The crystals of vanadinite are tabular on (0001). An analysis is given.

E. F. H

DESCRIPTION OF MINERALS FROM BELGIAN CONGO. H. Buttgenbach. *Mem. Acad. royale Belgique,* [2], **6**, no. 8, 33 pages, (1921).

In addition to "katangite" which has already been abstracted (*Am. Min.* **8**, 39, 1923) the following are described: Diamond in dodecatetrahedrons up to 0.8 carat. Native copper, in masses up to 6 kg. Bornite in grains in white calcite; when the latter is cleaved away, these are rough octahedrons with bright cube faces; chalcopyrite is sometimes present in the interior, and native copper on the surface; analysis is given, which seems to correspond to $Cu_{12}Fe_2S_9$, but the material analyzed was presumably a mixture. Pyrite occurs in crystals which are briefly described. Cuprite is found with the copper, and with it a black powder containing copper and cobalt oxides. Corundum and cymophane are found in sands. A tabular crystal of octahedrite is briefly described. The crystallography of the malachite is presented in detail, with figures; the common prism is $(\bar{3}23)$, and one new form $\lambda = (423)$ is announced. Crystallographic, chemical and optical data are given for a diopside. Dioptase is described crystallographically and an analysis given. Planchéite frequently accompanies the dioptase; it is asbestiform in character. Crystallographic data are given for cyanite, epidote, tourmaline, and staurolite. Finally, attention is called to the presence of pitchblende and its alteration products. E. T. W.

DIOPTASE AND PLANCHÉITE AT GUCHAB, SOUTH WEST AFRICA. M. Henglein. *Z. prakt. Geol.*, 53-6, (**1921**).

An analysis of the dioptase is given. It occurs in various associations with quartz, calcite, dolomite, malachite, planchéite, and chalcocite. E. F. H.

THE ISOMORPHIC RELATIONS OF THE SULPHO-SALTS OF LEAD AND COPPER. Wm. F. Foshag. *Am. J. Sci.*, **1**, 444-6, (1921).

Pb, on one hand, and Ag and Cu on the other, are not isomorphous in relationship and do not form mixed crystals. Ag-Pb and Cu-Pb sulpho-salts are double salts. E. F. H.

A CONTRIBUTION TO THE THEORY OF SOLID SOLUTIONS, MIX-CRYSTAL FORMATION AND ISOMORPHISM. J. Jakob. *Z. Krist.*, **56**, 295-304, (1921).

On the basis of highly complex coördinate formulas of some of the silicate minerals which show solid solution relations it is concluded that solid solution depends upon (1) similar spacial arrangement of molecules and (2) pure solution phenomena. E. T. W.

ADDITIONAL NOTES ON THE CRYSTALLOGRAPHY AND COMPOSITION OF BOULANGERITE. Earl V. Shannon. *Am. J. Sci.*, **1**, 423-6, (1921).

Boulangerite crystals from the Wood River district, Idaho, were measured. They are tabular parallel to *a*, and have a cleavage on that plane. The forms are: *a*(100), *N*(450), *n*(120), *g*(130), μ(140), *k*(180), *r*(210), *t*(310), ?(5.12.0), *z*(124). A new det'n of axial ratios gave: $a:b:c = .5038:1:.6862$. E. F. H.